Figure 16. Spruce needle rust was found at high levels in 1999.

Figure 17. Yellow-cedar decline occurs on approximately 500,000 acres in Southeast Alaska..

Figure 18. Spruce broom rust affects all species of spruce in Alaska.

Figure 19. This log end displays both hemlock fluting, and a hollow caused by white rot.

STATUS OF DISEASES

ECOLOGICAL ROLES OF FOREST DISEASES

The economic impacts of forest diseases in Alaska have been recognized for some time. In southeast Alaska, heart rot fungi cause substantial cull of nearly 1/3 of the gross volume in old-growth hemlock-spruce forests. Also a high incidence of cull in white spruce, paper birch, and aspen forests in the south-central and interior regions is considered a limitation on the availability and cost of harvesting timber. Traditionally, management goals sought to eliminate or reduce disease to minimal levels in an effort to maximize timber outputs. As forest management goals broaden to include enhancement of multiple resources and retaining structural and biological diversity, forest diseases management can be assessed from an ecological perspective.

We are learning that diseases are key ecological factors in Alaskan ecosystems. They enhance biological diversity, provide wildlife habitat, and alter forest structure, composition, and succession. As agents of disturbance in the western hemlock/Sitka spruce forests of southeast, diseases apparently contribute for the "breaking up" of even-aged stands as they are in transition (i.e., 150 to 200 years old) to old-growth phase. Then, they appear to be among the primary factors that maintain stability in the old-growth phase through small-scale (canopy-gap) level disturbance. Much less is known about the ecological role of diseases in south-central and interior forests, however diseases appear to be agents of small-scale disturbance in all successional stages of spruce and hardwood forests.

Figure 20. Decay fungi play vital roles in recycling nutrients and producing habitat for animals large and small.

Forest practices can be used to alter the incidence of diseases to meet management objectives. Two of the principal types of conifer disease that influence forest structure in Alaska, heart rot and dwarf mistletoe, can apparently be managed to predictable levels. If reducing disease to minimal levels is a management objective, then both heart rot and mistletoe can be largely eliminated through clearcut harvesting and even-aged management. However, to reduce disease to minimal levels in all instances is to diminish the various desirable characteristics of forest structure and ecosystems functions that they influence. Heart rot organisms and dwarf mistletoe provide unique forest structural components that may be lost for decades or perhaps centuries after clearcutting. Research indicates that harvesting practices other than clearcutting can be used to retain structural and biological diversity by manipulating these diseases to desired levels. Since heart rot in coastal stands is associated with natural bole scars and top breakage, levels of heart rot can be manipulated by controlling the incidence of bole wounding and top breakage during stand entries for timber removal. Levels of dwarf mistletoe can be manipulated through the distribution, size, and infection levels of residual trees that remain after harvest. Our ongoing research indicates that the incidence and effects of these diseases will vary through time in a predictable manner by whatever silvicultural strategy is used.

Research is currently underway in south-central and interior Alaska to assess the economic and ecological impacts of root diseases. Root diseases are difficult to detect, remain active on site in trees and stumps for decades, infect multiple age classes, and cause substantial volume loss. Ecologically, root diseases create canopy gaps that contribute to biodiversity, wildlife habitat, and succession. Elimination of root disease from an infected site is challenging because the infected material is primarily located in buried root systems. Establishment of non-host material within root rot centers is an effective option for manipulating levels of root disease. Ongoing research on the relationship between species composition and root disease incidence in south-central and interior Alaska will provide important information for both ecological and forest management considerations.

Table 3. Suspected effects of common diseases on major ecological characteristics and processes in Alaskan forests.

Effects by each disease of disorder are qualified as: - = negligible or minor effect, + = some effect, ++ = dominant effect.

ECOLOGICAL FUNCTION ALTERED

DISEASE	STRUCTURE	COMPOSITION	SUCCESSION	WILDLIFE HABITAT
STEM DISEASES				
Dwarf mistletoe	++	+	+	++
Hemlock cankers	-	+	-	+
Hardwood cankers	+	+	+	-
Spruce broom rust	+	-	-	++
Hemlock bole fluting	-	-	-	+
Western gall rust	-	-	-	-
HEART ROTS				
(Many species)	++	+	++	++
ROOT DISEASES				
(several species)	+	++	++	+
FOLIAR DISEASES				
Spruce needle rust	-	-	-	-
Spruce needle blights	-	-	-	-
Hemlock needle rust	-	-	-	-
Cedar foliar diseases	-	-	-	-
Hardwood leaf diseases	-	-	-	-
SHOOT DISEASES				
Sirococcus shoot blight	-	-	-	-
Shoot blight of yellow-cedar	-	+	-	-
DECLINES				
Yellow-cedar decline	++	++	++	+
ANIMAL DAMAGE				
Porcupines	+	-	-	+
Brown Bears	+	-	-	+
Moose	+	+	-	+

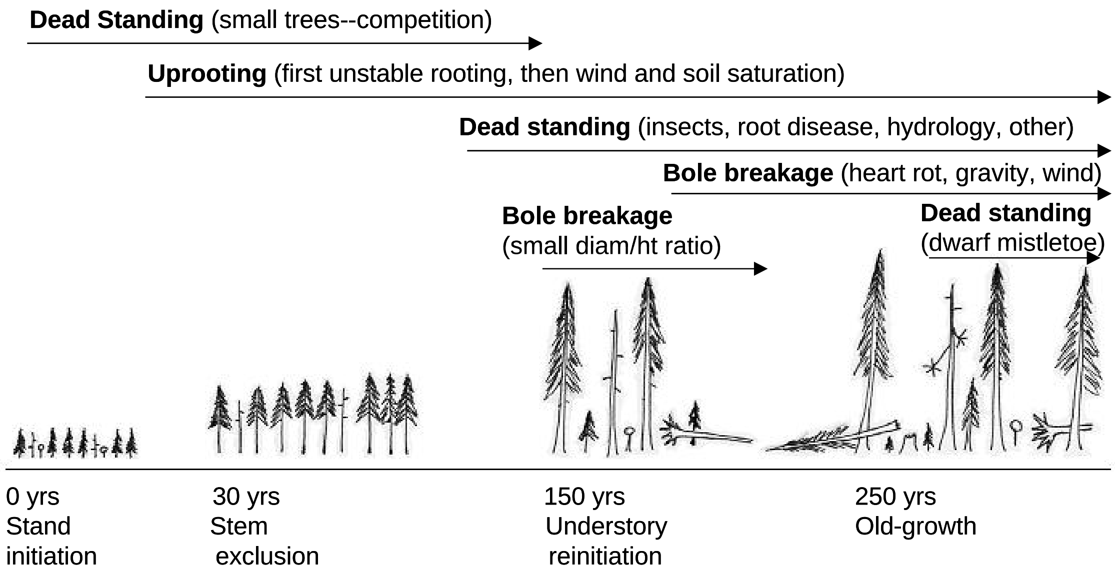

Figure 21. Stages of stand development and associated forms of tree mortality following catastrophic disturbance (e.g., clearcut or storm). Competition causes most mortality in young stands and trees usually die standing. Disease in the form of heart rot plays an active role in small-scale disturbance in the third, transitional stage and then is a constant factor in the maintenance of the old-growth stage. The time scale that corresponds to stages of stand development varies by site productivity. Many old-growth structures and conditions may be present by 250 years on some sites in Southeast Alaska. The old-growth stage may persist for very long periods of time in protected landscape positions.

STEM DISEASES

Hemlock Dwarf Mistletoe

Arceuthobium tsugense (Rosendhal) G.N. Jones

Hemlock dwarf mistletoe is an important disease of western hemlock in unmanaged, old-growth stands throughout southeast Alaska as far north as Haines. Although the range of western hemlock extends to the northwest along the Gulf of Alaska, dwarf mistletoe is absent from Cross Sound to Prince William Sound (M244A, 245A, and M245A)*. The incidence of dwarf mistletoe varies in old-growth hemlock stands in southeast Alaska from stands in which every mature western hemlock tree is severely infected to other stands in which the parasite is absent. The dominant small-scale (canopy gap) disturbance pattern in the old forests of coastal Alaska favors the short-range dispersal mechanism of hemlock dwarf mistletoe and may explain the common occurrence of the disease here. Infection of Sitka spruce is uncommon and infection of mountain hemlock is rare. The disease is uncommon on any host above elevations of approximately 1,000 feet. Heavily infected western hemlock trees have branch proliferations (witches' brooms), bole deformities, reduced height and radial growth, less desirable wood characteristics, greater likelihood of heart rot, top-kill, and severely infected trees may die. We have found the aggressive heart rot fungus *Phellinus hartigii* associated with large mistletoe brooms on western hemlock.

Figure 22. Large brooms are the most visible characteristic of hemlock dwarf mistletoe.

These symptoms are all potential problems in stands managed for wood production. Growth loss in heavily infested stands can reach 40% or more. On the other hand, witches' brooms, wood decay associated with bole infections, and scattered tree mortality can result in greater diversity of forest structure and increased animal habitat. Witches' brooms may provide hiding or nesting habitats for birds or small mammals, although this topic has not been adequately researched in Alaska. The inner bark of swellings and the seeds and shoots of the parasitic plants are nutritious and often consumed by small mammals (e.g., most likely flying squirrels). However, heavily infected hemlock stands can begin to decline and collapse to the extent that vertical structural diversity and animal habitat are diminished. Stand composition is altered when mixed-species stands are heavily infected; growth of resistant species such as Sitka spruce and cedar is enhanced.

Spread of the parasite into young-growth stands that regenerate following "clear cutting" is typically by: 1) infected non-merchantable hemlock trees (residuals) which are sometimes left standing in cut-over areas, 2) infected old-growth hemlocks on the perimeter of cut-over areas, and 3) infected advanced reproduction. Residual trees may play the most important role in the initial spread and long-term mistletoe development in young stands. Managers using alternative harvest techniques (e.g., large residuals left standing in clearcuts, small harvest units, or partial harvests) should recognize the potential reduction in timber volume and value from hemlock dwarf mistletoe under some of these silvicultural scenarios. But substantial reductions to timber are only associated with very high disease levels. High levels of hemlock dwarf mistletoe will only result if numerous, large, intensely-infected hemlocks are well-distributed after harvest. Mistletoe management appears to be a good tool in balancing several resource objectives. Selective harvesting techniques will be the silvicultural method for maintaining desirable levels of this disease if management intends to emphasize structural and biological diversity along with timber production.

* The number following place names refer to ecosystem section designations. Refer to page 6 and Appendix D.

Hemlock Canker

Xenomeris abietis Barr. and other fungi

Hemlock canker, which occurred at outbreak levels in southeast Alaska during the early 1990's, was conspicuous again in late 1999 on the Rowan Bay Road system of Kuiu Island and in the West Arm of Cholmondeley Sound on Prince of Wales Island. In past outbreaks, it has been common along unpaved roads on Prince of Wales Island, Kuiu Island (Rowan Bay road system), Chichagof Island (Corner Bay road system) and near Carroll Inlet on Revillagigedo Island (M245B). It was also observed in several roadless areas. This year, it was reported to be common on the Rowan Bay road system of Kuiu Island.

The causal agent has not been conclusively determined. Road dust and a fungus appear to be responsible for outbreaks of this disease. Ecologically, stand composition and structure are the primary effects of hemlock canker. Tree species, other than western and mountain hemlock, are resistant and benefit from reduced competition. Wildlife habitat, particularly for deer, may be enhanced where the disease kills understory hemlock; which tends to out-compete the more desirable browse vegetation.

Spruce Broom Rust

Chrysomyxa arctostaphyli Diet.

Broom rust is common on spruce throughout interior and south-central Alaska but is found in only several local areas of southeast Alaska (e.g., Halleck Harbor area of Kuiu Island and Glacier Bay (M245B)). The disease is abundant only where spruce grow near the alternate host, bearberry or kinnikinnick (*Arctostaphylus uva-ursi*) in Alaska. The fungus cannot complete its life cycle unless both host types (spruce and bearberry) are present.

Infections by the rust fungus result in dense clusters of branches or witches' brooms on white, Lutz, Sitka, and black spruce. The actual infection process may be favored during specific years, but the incidence of the perennial brooms changes little from year to year.

The disease may cause slowed growth of spruce, although this has not been determined by research. Witches' brooms may serve as entrance courts for heart rot fungi, including *Phellinus pini*.

Ecologically, the dense brooms provide important nesting and hiding habitat for birds and small mammals. In interior Alaska, research on northern flying squirrels suggests that brooms in white spruce are an important habitat feature for communal hibernation and survival in the coldest periods of winter.

Western Gall Rust

Peridermium harknessii J.P. Moore

Infection by the gall rust fungus *P. harknessii* causes spherical galls on branches and main boles of shore pine. The disease was common throughout the distribution of pine in Alaska in 1999 (M244B & C, M245B). Infected pine tissues are swollen but not always killed by the rust fungus. Another fungus, *Nectria macrospora*, colonized and killed many of the pine branches with *P. harknessii* galls this year. The combination of the rust fungus and *N. macrospora* frequently caused top-kill. The disease, although abundant, does not appear to have a major ecological effect in Alaskan forests.

HEART ROTS OF CONIFERS

Heart rot decay causes enormous loss of wood volume in Alaskan forests. Approximately 1/3 of the old-growth timber volume in southeast Alaska is defective largely due to heart rot fungi. These extraordinary effects occur where long-lived tree species predominate in such as old-growth forests in southeast Alaska. The great longevity of individual trees allows ample time for the slow-growing decay fungi to cause significant amounts of decay. Wood decay fungi play an important role in the structure and function of coastal old-growth forests where fire and other forms of catastrophic disturbance are uncommon. By predisposing large old trees to bole breakage, these fungi serve as important disturbance factors that cause small-scale canopy gaps. All major tree species in southeast Alaska are susceptible to heart rot decay and bole breakage.

In south-central and interior Alaska, heart rot fungi cause considerable volume loss in white spruce forests. Most heart rot fungi apparently enter trees through natural wounds, including dead or broken branches, frost cracks, and bole wounds. We have a limited understanding of the role of heart rot fungi in forest development. In the boreal forests, large-scale disturbance agents, including wildfire, insect outbreaks (e.g., spruce beetle), and flooding, are key factors influencing forest structure and composition. The importance of small-scale disturbances caused by decay fungi is unknown.

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Figure 23. ***Fomitopsis pinicola*** *is an important heartrot fungus in live trees but also a dominant decomposer of dead trees.*

Heart rot fungi enhance wildlife habitat -- indirectly by increasing forest diversity through gap formation and more directly by creating hollows in live trees or logs for species such as bears and cavity nesting birds.

Wood decay in both live and dead trees are centers of biological activity, especially for small organisms. Wood decay is the initial step in nutrient cycling of wood substrates, has associated bacteria that fix nitrogen, and contributes large masses of stable structures (e.g., partially modified lignin) to the humus layer of soils.

The importance of decay fungi in managed young-growth conifer stands is less certain. Wounds on live trees caused by logging activities allow for the potential of decay fungi to cause appreciable losses. Heart rot in managed stands can be manipulated to desirable levels by varying levels of bole wounding and top breakage during stand entries. In some instances, bole breakage is sought to occur in a specific direction (e.g., across streams for coarse woody debris input). Artificially wounding trees on the side of the bole that faces the stream can increase the likelihood tree fall in that direction. In southeast Alaska, a study has been concluded that investigated how frequently fungi enter wounds of different sizes and the rate of subsequent decay in these wounded trees. Generally, larger, deeper wounds and larger diameter breaks in tops result in a faster rate of decay. Results indicate that heart rot development is much slower in southeast Alaska than areas studied in the Pacific Northwest.

Table 4. Common wood decay organisms of live trees in Alaska

TREE SPECIES INFECTED

Heart and butt rot fungi*	Western hemlock	Sitka spruce	Western red cedar	White/Lutz spruce	Mountain hemlock
Laetiporus sulphureus	**X**	**X**		**X**	**X**
Phaeolus schweinitzii	**X**	**X**		**X**	
Fomitopsis pinicola	**X**	**X**		**X**	**X**
Phellinus hartigii	**X**				
Phellinus pini	**X**	**X**		**X**	**X**
Ganoderma sp.	**X**	**X**		**X**	
Armillaria sp.	**X**	**X**	**X**	**X**	**X**
Inonotus tomentosus				**X**	
Heterobasidion annosum	**X**	**X**			
Ceriporiopsis rivulosa			**X**		
Phellinus weirii			**X**		
Echinodontium tinctorium					**X**

* Some root rot fungi were included in this table because they are capable of causing both root and butt rot of conifers.

Wood decay fungi decompose branches, roots, and boles of dead trees; therefore, they play an essential role in recycling wood in forests. However, sap rot decay also routinely and quickly develops in spruce trees attacked by spruce beetles. Large amounts of potentially recoverable timber volume are lost annually due to sap rot fungi on the Kenai Peninsula, where salvage logging has not kept pace with tree mortality from the continuing spruce beetle epidemic. Significant volume loss from sap rot fungi typically occurs several years after tree death. The most common sap rot fungus associated with spruce beetle-caused mortality is *Fomitopsis pinicola*, the red belt fungus.

STEM DECAY OF HARDWOODS

Stem decay is the most important cause of volume loss and reduced wood quality in Alaskan hardwood species. In south-central and interior Alaska, incidence of stem decay fungi increases as stands age and is generally high in stands over 100 years. The most reliable decay indicator is the presence of fruiting bodies (mushrooms or conks) on the stem. Other external indicators of decay include frost cracks, broken tops, dead branch stubs, and trunk wounds. Stem decay fungi will limit harvest rotation age of forests that are managed for wood production purposes. Studies are currently underway in paper birch forests to identify the most important stem decay fungi and assess the relationships among decay, stand age, presence of decay indicators, and site factors.

Figure 24. ***Phellinus igniarius*** *conk on paper birch.*

Ecologically, stem decay fungi alter stand structure and composition and appear to be important factors in the transition of even-aged hardwood forests to mixed species forests. Bole breakage of hardwoods creates canopy openings, allowing release of understory conifers. Trees with stem decay, broken tops, and collapsed stems are preferentially selected by wildlife for cavity excavation. Several mammals, including the northern flying squirrel, are known to use tree cavities year-round for nest and cache sites.

In south-central and interior Alaska, the following fungi are the primary cause of wood decay in live trees:

Paper birch
Phellinus igniarius
Inonotus obliquus
Pholiota sp.
Ganoderma applanatum
Armillaria sp.

Trembling aspen
Phellinus tremulae
Pholiota sp.
Ganoderma applanatum
Armillaria sp.

A number of fungi cause stem decay in balsam poplar, black cottonwood, and other hardwood species in Alaska.

SHOOT BLIGHTS and CANKERS

Sirococcus Shoot Blight

Sirococcus strobilinus Pruess.

The shoots of young-growth western hemlocks were killed in moderate levels by the blight fungus *S. strobilinus* in southeast Alaska during 1999. Sitka spruce and mountain hemlock were attacked but less frequently and less severely. Thinning may be of some assistance in reducing damage by the fungus as thinned stands have fewer infections than unthinned stands.

This disease is typically of minimal ecological consequence because infected trees are not often killed and young hemlock stands are so densely stocked. Species composition may be altered to some degree where trees other than western hemlock may be favored by the disease.

Shoot Blight Of Yellow-cedar

Apostrasseria sp.

Yellow-cedar regeneration suffered infection and shoot blight by the fungus *Apostrasseria* sp. in southeast Alaska in 1999 as it does every year. The disease, however, does not affect mature cedar trees. Attack by the fungus causes terminal and lateral shoots to be killed back 10 to 20 cm on seedlings and saplings during winter or early spring. Entire seedlings up to 0.5m tall are sometimes killed. The newly discovered fungus that causes the disease, *Apostrasseria* sp., is closely related to other fungi that cause disease on plants under snow. The fungus *Herpotrichia juniperi* is often found as a secondary invader on seedlings after they die.

This shoot blight disease probably has more ecological impact than similar diseases on other host species because the natural regeneration of yellow-cedar is limited in many areas. By killing the leaders of yellow-cedar seedlings and diminishing their ability to compete with other vegetation, the pathogen reduces the regeneration success of yellow-cedar and thereby alters species composition.

Canker Fungi

Cryptosphaeria populina (Pers.) Sacc.
Cenangium singulare (Rehm.) D. & Cash
Ceratocystis fimbriata Ell. & Halst.
Cytospora chrysosperma Pers. ex Fr.
Nectria galligena Bres.

These fungi primarily cause trunk deforming cankers and wood decay of many hardwood species, particularly trembling aspen, in south-central and interior Alaska. Although most are considered weak parasites, *C. singulare* can girdle and kill a tree in three to ten years. All the canker-causing fungi were at endemic levels in 1999. Ecologically, canker fungi alter stand structure, composition, and successional patterns through trunk deformity and bole breakage.

FOLIAR DISEASES

Spruce Needle Blights

Lirula macrospora (Hartig) Darker
Lophodermium picea (Fuckel) Höhn.
Rhizosphaera pini (Corda) Maubl.

The fungus *Lirula macrospora* is the most important needle pathogen of spruce. In 1999 it occurred at moderate to low levels in most areas within the range of Sitka and white spruce. Throughout southeast Alaska, the disease was most common on young Sitka spruce and the lower crowns of larger trees. *Lophodermium picea* was present at low infection levels in 1999. This disease is more typical of larger, older trees of all spruce species in Alaska. *Rhizosphaera pini* continued at endemic levels after causing damage several years ago in coastal Alaska. Damage closely resembles that caused by spruce needle aphid. Microscopic observation of the tiny fruiting bodies on infected needles is necessary for proper identification.

The primary impact of these needle diseases is generally one of appearance. They can cause severe discoloration or thinning of crowns but typically have only negligible ecological consequence. However, repeated heavy infections may slow the growth of spruce and benefit neighboring trees, thereby altering species composition to some degree.

Spruce Needle Rust

Chrysomyxa ledicola Lagerh.
Chrysomyxa weirii Jacks.

Spruce needle rust, caused by *C. ledicola*, occurred at moderate levels across the state except in southeast Alaska where the disease was found at the highest levels in recent memory. Scattered outbreaks occurred in white spruce across south-central and interior Alaska in 1999. An extensive but unmeasured outbreak occurred on the west side of Cook Inlet near the Chilikadrotna River (M213A). Acres attributed to this foliar disease should be considered conservative because the timing of aerial surveys is prior to peak visible expression of the disease.

The disease was epidemic in southeast Alaska in wet, boggy areas wherever spruce and Labrador-tea coexisted. Up to 100% of current-year's needles were infected in spruce in many of these areas, giving the forest a bright yellow appearance. Buds were not infected, however, and even with such high disease levels, nearly all trees should recover.

The spores that infect spruce needles are produced on the alternate host, Labrador-tea (*Ledum spp.*), a plant that is common in boggy areas; thus the disease on spruce is most pronounced in these boggy (muskeg) areas. Although the disease can give spruce trees the appearance of being nearly dead, trees rarely die of this disease even in years of intense infection.

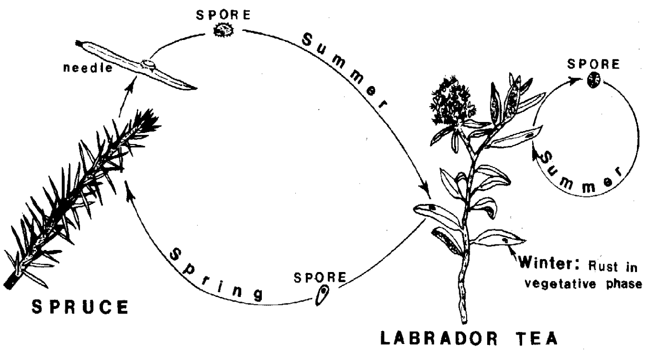

Figure 25. The life cycle requires two host plants: spruce and Labrador tea.

On Sitka spruce, the primary ecological consequence of the disease may be to reduce tree vigor of a species already poorly adapted to boggy sites. Repeated infection of spruce may alter forest composition by favoring other tree species.

The foliar rust fungus *C. weirii* was found sporulating on one-year-old Sitka spruce needles in several areas of southeast Alaska during spring but it has never been detected at threatening levels. Unlike most other rust fungi, no alternate host is necessary to complete its life cycle. Little ecological or economic impact results from this disease.

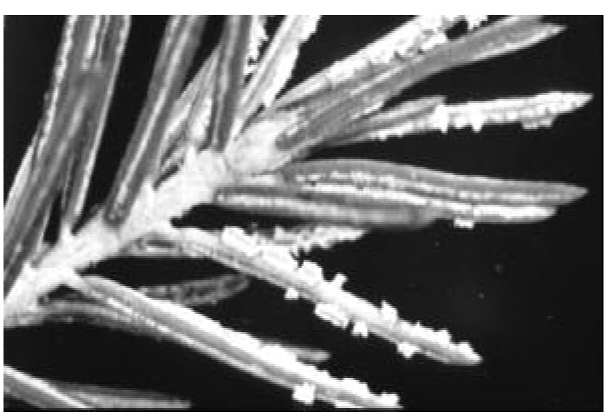

Figure 26. The small fruiting bodies of ***Chrysomyxa ledicola*** *can be seen on the needles of this spruce.*

Hemlock Needle Rust

Pucciniastrum vaccinii (Rab.) Joerst.

Hemlock needle rust was found at low endemic levels in 1999 after a high incidence three years ago. In 1996, the disease was most damaging near Yakutat (245A) where it caused defoliation of western hemlock, especially on trees growing adjacent to harvested sites. Elsewhere, infected needles were found, but hemlock trees were not heavily defoliated. The alternate hosts for the rust fungus include several blueberry species (*Vaccinium*). Infection levels usually return to endemic levels in a year or so and the disease is not expected to influence major ecological change.

Willow Rust

Melampsora epitea Thuem.

Willow rust, caused by one or more races of *Melampsora epitea*, occurred on willow at moderate to high levels in 1999. Acres attributed to this foliar disease should be considered conservative because the timing of aerial surveys is prior to peak expression of the disease. The primary outbreak coincided with the large outbreak of the willow leaf blotchminer across the interior. The rust fungus causes a yellow leaf spot or blight on willow leaves. Tamarack is an alternative host for the rust, however, the fungus does not need to alternate to the conifer host. The rust fungus overwinters on willow leaves or buds and can infect willows in successive years. Repeated rust infection of leaves may reduce host vigor.

Foliage Diseases of Cedars

Gymnosporangium nootkatense Arth.
Didymascella thujina (Durand) Maire

Two fungi that infect the foliage of cedar, *G. nootkatense* on yellow-cedar and *D. thujina* on western redcedar, occurred at endemic levels this year. *D. thujina* was the more damaging of the two and was common wherever its host was found. Neither fungus resulted in severe defoliation or death of cedar trees. Neither disease has major ecological effects.

ROOT DISEASES

Three important tree root diseases occur in Alaska: tomentosus root rot, annosus root disease, and armillaria root disease. The laminated root disease caused by a form of the fungus *Phellinus weirii*, so important in some western forests of British Columbia, Washington, and Oregon, is not present in Alaska. A non-root disease form of the fungus is present in southeast Alaska, where it causes a white rot in western redcedar, contributing to the very high defect levels of this tree species.

Although relatively common in Alaskan forests, root diseases are often mis-diagnosed or overlooked. Recognizing root disease can be challenging because the infected tissue is primarily below ground and infected trees may be symptomless. Identification of a root disease can seldom be made solely on the basis of above-ground symptoms.

Root disease pathogens affect groups of trees in progressively expanding disease centers. Typically, disease pockets contain dead trees in the center and living, but infected trees in various stages of decline, at the edges. Root disease fungi are capable of spreading from tree to tree through root contacts. Infected trees are prone to uprooting, bole breakage, and outright mortality due to the extensive decay of root systems and the lower tree bole. Volume loss attributed to root diseases can be substantial, up 1/3 of the gross volume. In managed stands, root rot fungi are considered long-term site problems because they can remain alive and active in large roots and stumps for decades, impacting the growth and survival of susceptible host species on infected sites.

Ecologically, root diseases are considered natural, perhaps essential, parts of the forest altering stand structure, composition, and increasing plant community diversity through canopy openings and scattered mortality. Resistant tree species benefit from reduced competition within infection centers. Wildlife habitat may be enhanced by small-scale mortality centers and increased volume of large woody downed material.

Tomentosus Root Disease

Inonotus tomentosus (Fr.) Teng.

I. tomentosus causes root and butt-rot of white, Lutz, Sitka, and black spruce. The fungus can also attack lodgepole pine and tamarack. All hardwood trees are resistant to infection. The disease appears to be widespread across the native range of spruce in south-central and interior Alaska**,** but to date, has not been found in southeast Alaska.

Spruce trees of all ages are susceptible to infection through contact with infected roots. Infected trees exhibit growth reduction or mortality, depending on age. Younger trees may be killed outright while older trees may persist in a deteriorating condition for many years. Volume loss in older infected trees can be substantial, up 1/3 of the gross volume. Trees with extensive root and butt decay are prone to uprooting and bole breakage. Individual mortality centers (groups of infected trees) are typically small, however, coalescing centers can occupy large areas.

*Figure 27 A white spruce sapling killed by the root disease **I. tomentosus**.*

Studies in cut-over stands indicate that *I. tomentosus* will remain alive in colonized stumps for at least three decades, and successfully attack adjacent trees through root contacts. Thus, spruce seedlings planted within close proximity of infected stumps are highly susceptible to infection through contacts with infected roots. Recognition of this root disease is important in managed stands where natural regeneration of white and Lutz spruce is limited and adequate restocking requires planting.

Tomentosus root disease can be managed in a variety of ways depending on management objectives. Options for manipulating levels of root disease on infested sites include: establishment of non-susceptible species in root rot centers (i.e., hardwood trees), avoid planting susceptible species within close proximity of diseased stumps, and removal of diseased stumps and root systems. Studies are currently underway to assess mortality in young growth stands and determine site factors that influence disease incidence and severity.

Annosus Root & Butt Rot

Heterobasidion annosum (Fr.) Bref.

Annosus commonly causes root and butt-rot in old-growth western hemlock and Sitka spruce forests in southeast Alaska (M245B, M244C). To date, *H. annosum* has not been documented in south-central or interior Alaska.

Elsewhere in the world, spores of the fungus are known to readily infect fresh stump surfaces, such as those found in clearcuts or thinned stands. Studies in managed stands in southeast Alaska, however, indicate limited stump infection and survival of the fungus. Thus, this disease poses minimal threat to young managed stands with stump top infection.

Reasons for the limited stump infection may be related to climate. High rainfall and low temperatures, common in Alaska's coastal forests, apparently hinder infection by spores.

Armillaria Root Disease

Armillaria spp**.**

Several species of *Armillaria* occur in the coastal forests of southeast Alaska, but in general, the species are less-aggressive, saprophytic decomposers that only kill trees when they are under some form of stress. Studies in young managed stands indicate that *Armillaria sp*. can colonize stumps, but will not successfully attack adjacent trees.

Figure 28. A lesion of dead tissue colonized by ***Armillaria.***

Several species of *Armillaria* occur in south-central and interior Alaska, some attack conifers while others attack hardwoods. Most species appear to be weak pathogens invading trees under stress. Research is currently underway to determine the species present and their impacts in the boreal forests.

DECLINES AND ABIOTIC FACTORS

Yellow-cedar Decline

Decline and mortality of yellow-cedar persists as one of the most spectacular forest problems in Alaska. Approximately 479,000 acres of decline have been mapped during aerial detection surveys. Concentrated mortality occurs in a wide band from western Chichagof and Baranof Islands to the Ketchikan area (M245B).

All research suggests that contagious organisms are not the primary cause for this extensive mortality. Some site factor, probably associated with poorly-drained anaerobic soils, appears to be responsible for initiating and continuing cedar decline. Two hypotheses have been proposed to explain the primary cause of death in yellow-cedar decline:

- Toxins are produced by decomposition in the wet, organic soils, or
- Shallow fine roots are damaged from freezing, associated with climatic warming and reduced insulating snowpack in the last century.

These hypotheses are developed in some detail (Hennon and Shaw 1994, 1997). Interestingly, considerable concentrations of newly-killed trees were evident in declining forests during 1996 and 1997, perhaps a response to the unusually prolonged cold temperatures with little snowpack that persisted during the previous two winters. Whatever the primary cause of this mysterious decline, all available information indicates that it is probably a naturally-occurring phenomenon. We initiated preliminary investigations this year in the areas of soils and hydrology with more detailed research planned for next year.

Research suggests that the total acreage of yellow-cedar decline has been increasing very gradually; the slow increase in area has been a result of the expansion of existing decline (<3 feet/year). Most stands contain trees that died up to 100 years ago (snags still standing), as well as recently killed cedars, dying cedars (with yellow, red, or thinning crowns), healthy cedars, and other tree species.

Ground surveys show that 65% of the basal area of yellow-cedar is dead on this acreage. Other tree species are affected in different ways: on some sites they produce increased growth, presumably due to less competition, and on other sites they experience slowed growth and mortality due to deteriorating site conditions (poor drainage). Species change to western hemlock and mountain hemlock and large increases in understory biomass accumulation for brushy species appear to be occurring in some stands where decline has been ongoing for up to a century.

Figure 29. Death of overstory yellow-cedar trees favors other tree species.

The primary ecological effect of yellow-cedar decline is to alter stand structure (i.e., addition of numerous snags) and composition (i.e., yellow-cedar diminishing and other tree species becoming more numerous) that leads to eventual succession favoring other conifer species. The creation of numerous snags is probably not particularly beneficial to cavity-using animals because yellow-cedar wood is less susceptible to decay. Region-wide, this excessive mortality of yellow-cedar may lead to diminishing populations (but not extinction) of yellow-cedar, particularly when the poor regeneration of the species is considered.

The large acreage of dead yellow-cedar and the high value of its wood suggest opportunities for salvage. Cooperative studies with the Wrangell Ranger District, the Forest Products Laboratory in Madison, Wisconsin, Oregon State University, and State and Private Forestry are investigating the mill-recovery and wood properties of snags of yellow-cedar that have been dead for varying lengths of time. This work includes wood strength properties, durability (decay resistance), and heartwood chemistry.

Little is known about wildlife use and dependency of yellow-cedar forests. In 1998, we initiated a study to evaluate birds' use of each of the snag classes as nesting or feeding habitat. In a companion study we are investigating the insect community on dead cedars;

insects on recently killed trees may be an important prey source for insectivorous birds.